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Expiratory Muscle Training Versus Functional Electrical Stimulation on Pulmonary and Swallowing Functions in Acute Stroke Patients

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ABSTRACT

INTRODUCTION. Post-stroke dysphagia is reported in 30–50 % of stroke population. It increases mortality rate and leads to serious complications such as expiratory muscle affection which is a major cause of defective swallowing and ineffective airway protection. Expiratory muscle strength training (EMST) and functional electrical stimulation (FES) are recommended techniques to improve expiratory muscles performance.

AIM. To compare the effect of EMST to that of FES on pulmonary and swallowing functions in acute stroke patients.

MATERIAL AND METHODS. Seventy-two patients with post-stroke dysphagia were divided into two groups. Both groups received traditional dysphagia treatment. In addition, the first group received EMST and the second received neck and abdominal FES. Pulmonary functions were measured before and after in form of forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio and peak expiratory flow (PEF), and arterial blood gases (ABG) while the Gugging Swallowing Scale (GUSS) was used as an indicator of swallowing function results of both groups were compared after one month of treatment.

RESULTS. The post-treatment GUSS, FVC, FEV1 and PEF of the EMST group showed more significant increase compared to the FES group ($p < 0.05$) with no significant differences in FEV1/FVC ($p > 0.05$). Regarding ABG, there was more significant decrease in $PaCO_2$ and HCO3 of EMST group compared to FES group ($p < 0.01$).

CONCLUSION. EMST was more effective than FES when it comes to improving expiratory and swallowing functions in patients with post-stroke dysphagia.

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KEYWORDS: humans, deglutition, deglutition disorders, forced expiratory volume, vital capacity, electric stimulation.

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Тренировка экспираторных мышц в сравнении с функциональной электростимуляцией для улучшения легочной и глотательной функций у пациентов после острого инсульта

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РЕЗЮМЕ

ВВЕДЕНИЕ. Постинсультная дисфагия отмечается у 30-50 % пациентов, перенесших инсульт. Она повышает смертность и приводит к таким серьезным осложнениям, как поражение экспираторной мускулатуры, являющееся основной причиной нарушения глотания и неэффективной защиты дыхательных путей. Тренировка силы экспираторных мышц и функциональная электростимуляция являются рекомендуемыми методами для улучшения работы дыхательных мышц.

ЦЕЛЬ. Сравнить влияние тренировки силы экспираторных мышц и функциональной электростимуляции на легочную и глотательную функции у пациентов после острого инсульта.

МАТЕРИАЛ И МЕТОДЫ. Семьдесят два пациента с постинсультной дисфагией были разделены на две группы. Обе группы получали традиционное лечение дисфагии. Кроме того, в первой группе проводилась тренировка экспираторной мускулатуры, а во второй — функциональная электростимуляция шеи и брюшной полости. Легочные функции измерялись до и после лечения в виде форсированной жизненной емкости (FVC), форсированного экспираторного объема за одну секунду (FEV1), соотношения FEV1/FVC и пикового экспираторного потока (PEF), газов артериальной крови (ABG), в то время как тест Gugging Swallowing Scale (GUSS) использовался как показатель функции глотания. Результаты обеих групп сравнивались после одного месяца лечения.

РЕЗУЛЬТАТЫ. После лечения GUSS, FVC, FEV1 и PEF в группе тренировки силы экспираторных мышц достоверно увеличились по сравнению с группой функциональной электростимуляции ($p < 0,05$) при отсутствии значимых различий по показателям FEV1/FVC ($p > 0,05$). Что касается (ABG) газов артериальной крови, то в группе тренировки силы экспираторных мышц (EMST) наблюдалось более значительное снижение $PaCO_2$ и HCO3 по сравнению с группой функциональной электростимуляции (FES) ($p < 0,01$).

ЗАКЛЮЧЕНИЕ. Тренировка силы экспираторных мышц оказалась более эффективной, чем функциональная электростимуляция, в отношении улучшения экспираторной и глотательной функций у пациентов с постинсультной дисфагией.

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КЛЮЧЕВЫЕ СЛОВА: люди, заглатывание, нарушения заглатывания, объем форсированного выдоха, жизненная емкость, электростимуляция.

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INTRODUCTION

Stroke is considered a primary cause of mortality and residual disability all over the globe, it also leads to a variety of complications that prolong hospitalization and place a significant burden on the healthcare system [1]. In Egypt, the annual incidence of stroke is approximately 150,000–210,000 and stroke accounts for 6.4 % of all deaths and ranks third after cardiovascular and gastrointestinal diseases [2, 3]. One of the most affected systems by stroke is the respiratory system; it goes through detrimental changes including weak respiratory muscles, ineffective airway clearance, reduced chest wall compliance and abnormal respiratory patterns which in turn lead to poor airway protection and weak cough reflex [4]. Cough plays a vital role in airway protection as it is a strong defense mechanism that prevents foreign body aspiration. For cough to be effective, critically-ill patients in general and stroke patients in particular must demonstrate expiratory muscles of sufficient strength [5]. Affection of expiratory muscles in conjunction with impaired swallowing is reported in as high as 30–50 % of stroke survivors [6]. Post-stroke swallowing disorder further increases the mortality risk in this patient group because it makes them more prone to aspiration pneumonia, malnutrition, and dehydration [7]. In terms of prognosis of post-stroke dysphagia, spontaneous recovery within the first seven days was reported in 50 % of patients. The remaining percentage who did not demonstrate

spontaneous recovery in the early stages may fully or partially recover with the help of dysphagia treatment. [8] therefore, proper diagnosis and appropriate treatments are important [9].

Expiratory muscle strength training (EMST) is a therapeutic approach used to indirectly improve swallowing functions by performing resisted expiration through the mouth [9] overloading the expiratory muscles triggers new fiber formation, muscle hypertrophy, and better adaptability to increased ventilatory demands. It also contributes to better pharyngeal and laryngeal muscle control involved in speech production and swallowing [10]. Strengthening the expiratory muscles leads to significant improvement in peak flow and swallowing functions, when assessed by swallowing ability, food intake and penetration/aspiration [11]. Moreover, it results in more efficient clearance of supraglottic and tracheal secretions or aspirated food and water which subsequently reduces risk of aspiration and aspiration-related complications such as pneumonia and malnutrition. Additionally, improved PEF may reduce the risk of death, as it has recently been considered a good predictor of the survival rate in the older population [11].

Electrical stimulation (FES) is an intervention that improves the respiratory function, increases respiratory muscles' strength, endurance, and speed of contraction, diaphragmatic thickness, as well as lung volumes and flows [12]. When FES was applied on the abdominal muscles, a measurable increase was witnessed in vital capacity (VC), forced vital capacity (FVC), and peak expiratory flow (PEF) in comparison with the initial measurements. Improvement of these values led to a significant improvement in the peak flow of cough [13,14] FES was further used in dysphagia treatment to increase patients' swallowing mechanism by achieving stronger swallowing muscles and promoting the recovery of the cortical control of swallowing [7]. Using muscular electrical stimulation along with traditional exercises yields promising therapeutic benefits, especially for patients with post-stroke dysphagia [7]. Although, there are several proven methods used to treat dysphagia in acute stroke survivors, there is lack of publications comparing the effect of EMST and FES for abdomen and neck in these patients.

AIM

To compare EMST and FES in order to determine the most effective technique for improving patients' ability to swallow and reduce their risk of aspiration and pneumonia during the early stage when the chances of recovery are potentially higher. In our hypothesis, we suggested that EMST and FES are effective techniques for improving swallowing and pulmonary function in acute stroke patients.

MATERIALS AND METHODS

This controlled parallel randomized research adopted the latest CONSORT Statement [15] and was carried out in compliance with the Helsinki Declaration. Prior to the active enrollment of the participants, a written informed consent was obtained from each participant or their surrogate after a detailed explanation of the study's objectives and procedures. The study began in October 2021 after getting the institutional ethics board approval (P.T.REC/012/003420), and registered with Pan-African Clinical Trials Registry (PACTR202205908494752).

Study Participants

Patients who were considered fit to participate were of both genders, aged between 55 and 65 years, body mass indices (BMI) ranged between 25 and 29.9 kg/m2, diagnosed with acute ischemic stroke with dysphagia confirmed by computed tomography or Magnetic resonance imaging (MRI), hemodynamically and medically stable and in good cognition that enabled them to comprehend the study requirements. Included patients' spirometric measures fell within the following features [5] forced expiratory volume in one second (FEV1) and FVC: 60–69 %, FEV1/FVC: < 80 % and PEF: 50–80 %, they must have demonstrated moderate to severe dysphagia based on the GUSS score 0–14 [7] with evident presence of arterial blood gases abnormalities upon intensive care unit (ICU) admission.

On the other hand, patients were considered ineligible for participation in the study if they showed evidence of hemorrhagic stroke, showed signs of cognitive and psychiatric disorders or impairment (i.e., Glasgow coma scale < 11), found unable to follow instructions (e.g., in case of sensory aphasia, blindness, dementia, and deafness), showed paralysis or affection of facial muscles upon examination, showed or developed uncontrolled metabolic and cardiovascular conditions or complications, had one or more contraindications to abdominal electrical stimulation (e.g., cardiac pace maker, acute abdominal surgery, acute neck surgery, tracheostomy and skin diseases) or had been previously diagnosed with orthopedic, neurological, or chest disorders that affected trunk muscles control or caused respiratory disorders as chronic obstructive pulmonary disease (COPD).

Data Collection

Patient data were obtained from admission notes, progress notes, ICU flow sheets, laboratory results, demographics (age, gender, and body mass index (BMI)), the physician's diagnosis based on physical examination and radiological findings in addition to physical therapy assessment. The presence of exclusion factors was assessed within the first 24 hours after inclusion. The respiratory function was measured via forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), peak expiratory flow (PEF), as soon as possible after the participant was able to breathe independently and follow instructions. When possible, each measurement was repeated until three reproducible results within 5 % were registered, and the greatest value used for analysis.

Participants' Eligibility

All consecutive admissions ($n = 127$) between October 2021 and December 2022 were assessed for eligibility, 72 patients were randomized, 55 patients were omitted because they did not match the inclusion criteria, through the evaluation, 12 participants were drop out from the study (5 withdrew, 3 developed cardiovascular complications not related to the intervention, 2 had cognitive deterioration, 2 did not commit to completing the sessions after ICU discharge) as demonstrated in Figure 1. Finally, 60 participants completed the intervention and the analysis, and only they were included in the data analysis.

Randomization and blinding

Participants were randomly assigned to EMST group and FES group which were labeled initially as Group A and B respectively. A statistician (not a member of the research team) performed a masked centralized randomized method

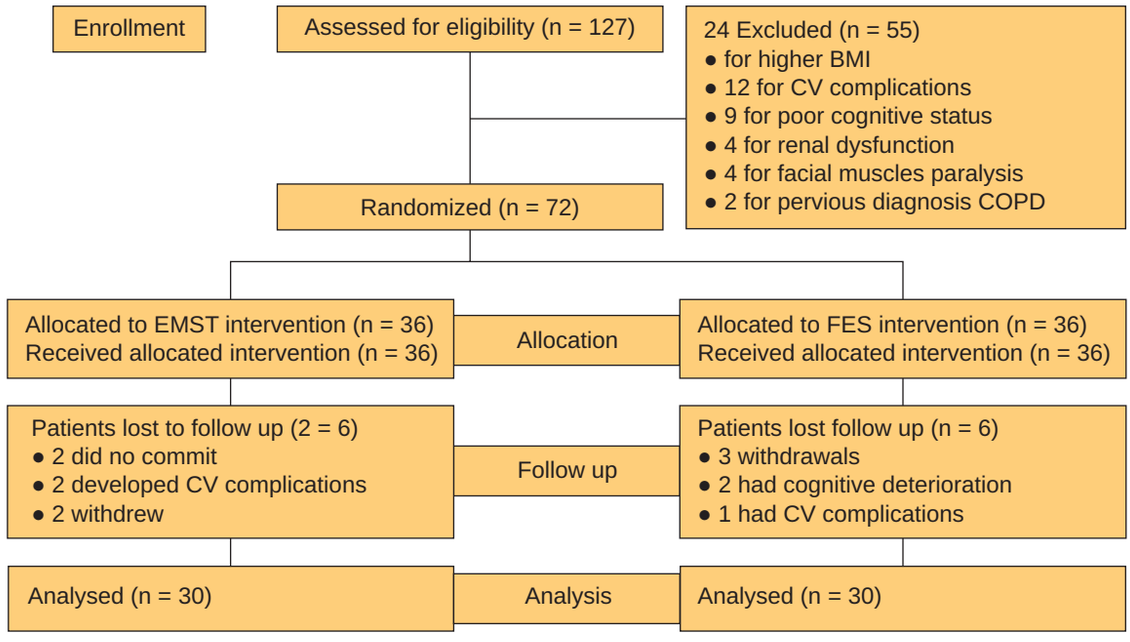

Fig. 1. Flowchart demonstrating patient who were assessed and enrolled and those who completed the study

with allocation concealment in which the participants and research team members (except the physiotherapists involved in the intervention) were unaware of the assignment. The randomization sequence was created with R Software (version 2.11) and segregated by gender, age (60–75 years), and BMI. To keep an even number of participants in each group, block sizes were varied at random between four and eight. Furthermore, the participants in each group received their exercise in private to keep all participants blinded.

Intervention

After initial screening, pre-treatment assessment and randomization, participants were treated according to the group they are enrolled in as follows:

Expiratory Muscle Strength Training (EMST) Group

This group included 36 (30 completed and 6 dropped out) acute stroke patients with dysphagia. They received expiratory muscle strength training using (EMST 150) device (Aspire Products LLC., USA) in addition to the traditional dysphagia exercises.

EMST Progression

On day 1, the participants who were enrolled in this group underwent the initial assessment of the pulmonary function (FEV1, FVC, FEV1/FVC and PEF), ABG, SPO2 and the swallowing function (GUSS) within 24 hours of enrolment. All initial data was recorded for documentation and comparison. EMST treatment was also started within 24 hours of enrolment and after initial assessment was completed. The training lasted for a total of 30 minutes of EMST including rest periods. The frequency of treatment was 1 session/day, 5 days/week for a total of 4 weeks [6]. In each session, EMST was performed in form of sets of 5 breaths with 15–30 sec rest in between breaths and a 1-minute rest between sets. The Intensity was started at the first tolerated resistance and was progressed by ¼ knob turn for every week of training as directed in the device manual. [16] After completing 4 weeks of training final assessment was conducted to resemble the initial assessment: the pulmonary function (FEV1, FVC, FEV1/FVC and PEF), ABG, SPO2 and the swallowing function (GUSS).

Functional Electrical Stimulation (FES) Group

This group included 36 (30 completed and 6 dropped out) acute stroke patients with dysphagia. They received electrical stimulation on the neck and abdomen using (Ev-906,4CH Digital TENS/EMS, Taiwan) device in addition to the traditional dysphagia exercises. Electric stimulation was applied to the anterior neck and laryngeal elevator muscles of the larynx above and below the hyoid bone using four surface electrodes and applied for the abdomen to stimulate rectus abdominis and external oblique muscles bilaterally using two stimulation channels.

FES Application and Progression

On day 1, the participants who were enrolled in this group underwent the initial assessment of the pulmonary function (FEV1, FVC, FEV1/FVC and PEF), ABG, SPO2 and the swallowing function (GUSS) within 24 hours of their enrolment. All initial data was recorded for documentation and comparison. FES treatment was started within 24 hours of enrolment and after initial assessment was completed. Abdominal and neck muscle FES were conducted for a total of 30 minutes each in separate times of the day with at least 30 minutes of rest in between both applications [14, 17]. The treatment was continued for the duration of the study (i.e., a total of 4 weeks). Stimulation parameters were different for neck and abdominal muscles as stated in table 1. Patients were encouraged to swallow during the neck FES and were encouraged to forcefully but slowly exhale, huff and cough during abdominal FES. After completing 4 weeks of training, a final assessment was conducted to resemble the initial assessment: the pulmonary function (FEV1, FVC, FEV1/FVC and PEF), ABG, SPO2 and the swallowing function (GUSS).

Table 1. Parameters of neck and abdomen FES

Parameter	Neck FES	Abdominal FES
Frequency, Hz	30–50	Up to 80
Amplitude, mA	25–400	0–25
Pulse Width, μs	25–400	25–400
Progression limit	Up to the reported feeling of deep tension and limited by patient tolerance	Up to palpable contraction and limited by patient tolerance
Imitating functions	Patients were encouraged to swallow repeatedly as they feel the tension in their neck	Patients were encouraged to forcefully but slowly exhale, huff and cough along with the muscle contraction

Traditional Dysphagia Therapy

Both groups received conventional dysphagia treatment including (volume and texture modifications, strategies such as chin tuck, head tilt, head turn, effortful swallow, supraglottic swallow, super-supraglottic swallow, Mendelsohn maneuver and exercises such as the Shaker exercise and Masako (tongue hold) maneuver in addition to chest physiotherapy if needed.

Outcomes

Initially, all patients were assessed for primary and secondary outcomes on the first day of inclusion and re-assessed by the same blinded physiotherapist after 4 weeks of treatment. The assessment included:

Primary Measured Outcomes

These measurements included pulmonary function parameters in form of FVC, FEV1, FEV1/FVC and PEF, using Hand held lung function spirometry (CONTECTM Model:CMS501, Made in China) as well as swallowing function represented by Gugging Swallowing Scale (GUSS). These measurements were used to correlate the improvement in the expiratory muscle strength and the improvement in the swallowing function.

Secondary Measured Outcomes

Including Oxygen Saturation (SPO2) and Arterial Blood Gases (ABG) in form of PaO2, PCO2, PH and HCO3 using Arterial blood gases analyser (Abbott Laboratories Pharmaceutical Company, Singapore)

Statistical Analysis

Sample size calculation was performed using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) based on data of FEV1 derived from pilot study conducted on 5 subjects in each group; and revealed that the required sample size required for this study was 30 subjects in each group. Calculation is made with α=0.05, power = 80 % and effect size = 0.54 a maximum drop-out percentage of 17 % was allowed in each group.

Unpaired t-test was implemented to compare the results between the two groups. Chi squared test was conducted for comparison of sex distribution between the groups. The Shapiro-Wilk test was used to check the normal distribution of the data. The homogeneity of variances was checked using Levene's test for homogeneity of variances. Mixed MANOVA was conducted to measure the effect the treatment had on GUSS, pulmonary function and atrial blood gases. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. The level of significance for all statistical tests used in this study was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

RESULTS

Table 2 shows the subject characteristics of EMST and FES groups respectively. There was no significant difference between the two groups in terms of weight, age, heigh, BMI and sex distribution ($p > 0.05$).

Table 2. Comparison of subject characteristics between the EMST and FES Groups

Parameter	EMST Group	FES Group	MD	t-value	*p*-value
	Mean ±SD	Mean ±SD			
Age, years	60.53 ± 3.18	59.7 ± 3.56	0.83	0.95	0.34
Weight, kg	72.86 ± 6.63	73.03 ± 5.95	−0.17	−0.1	0.91
Height, cm	164.2 ± 6.67	163.6 ± 6.42	0.6	0.35	0.72
BMI, kg/m²	26.97 ± 1.01	27.25 ± 1.03	−0.28	−1.06	0.29
Sex, n (%)					
Females	16 (53 %)	14 (47 %)		χ^2= 0.26	0.61
Males	14 (47 %)	16 (53 %)			

Note: *SD — Standard deviation; MD — Mean difference; χ^2 — Chi-squared test; BMI — body mass index.*

Table 3. Comparison of the primary outcomes in EMST and FES groups

	Pre-treatment	Post-treatment			
	Mean ± SD	**Mean ± SD**	**MD**	**% of change**	***p* value**
GUSS					
EMST Group	7.8 ± 1.95	12.8 ± 1.24	−5	64.10	0.001
FES Group	8.07 ± 1.36	10.86 ± 1.71	−2.79	34.57	0.001
MD	−0.27	1.94			
	***p* = 0.54**	***p* = 0.001**			
FVC (L)					
EMST Group	2.32 ± 0.27	2.94 ± 0.31	−0.62	26.72	0.001
FES Group	2.34 ± 0.32	2.73 ± 0.36	−0.39	16.67	0.001
MD	−0.02	0.21			
	***p* = 0.81**	***p* = 0.02**			
FEV1 (L)					
EMST Group	1.78 ± 0.25	2.39 ± 0.24	−0.61	34.27	0.001
FES Group	1.79 ± 0.22	2.18 ± 0.25	−0.39	21.79	0.001
MD	−0.01	0.21			
	***p* = 0.88**	***p* = 0.001**			
FEV1/FVC (%)					
EMST Group	76.57 ± 5.74	81.7 ± 8.55	−5.13	6.70	0.001
FES Group	76.46 ± 3.31	79.83 ± 3.95	−3.37	4.41	0.01
MD	0.11	1.87			
	***p* = 0.92**	***p* = 0.28**			
PEF (L/min)					
EMST Group	402.76 ± 100.16	528.93 ± 92.37	−126.17	31.33	0.001
FES Group	394.49 ± 98.76	448.14 ± 81.11	−53.65	13.60	0.006
MD	8.27	80.79			
	***p* = 0.74**	***p* = 0.001**			

Note: *SD — Standard deviation; MD — Mean difference; GUSS — The Gugging Swallowing Screen; EMST — Expiratory Muscle Strength Training; FES — Functional Electrical Stimulation; FEV1 — Forced Expiratory Volume in 1st Second; FVC — Forced Vital Capacity; PEF — Peak Expiratory Flow.*

1. Effect of treatment vs. time on GUSS, PF and ABG

Using Mixed MANOVA a clinically significant interaction effect of treatment and time was measured (F = 4.03, p = 0.001). There was a significant main effect of treatment (F = 2.71, p = 0.01). There was a significant main effect time (F = 70.7, p = 0.001).

2. Within-Group Comparison

Both groups showed significant increases in all primary measurements after the treatment compared with the pre-treatment measurements ($p > 0.01$). (Table 3). Regarding secondary measurements, both groups showed a significant increase in PaO2, SPO2 and pH and a significant decrease in PaCO2 and HCO3 post-treatment compared with the pre-treatment values ($p < 0.01$) (Table 4).

3. Between-Group Comparison

When both groups were compared, EMST group showed more significant increase in main outcomes compared FES group ($p < 0.05$) except FEV1/FVC that revealed no significant difference ($p > 0.05$) (see Table 3). For secondary measurements, there was a significant decrease in PaCO2 and HCO3 of the EMST group compared with that of the FES group ($p < 0.01$), while there was no significant difference in PaO2, SPO2 and pH ($p > 0.05$) (see Table 4).

Adverse Events of Applied Intervention

Over the course of this study, no adverse events from EMST application or FES were reported, as documented in weekly

interviews to record any adverse events experienced by the participants.

DISCUSSION

Even though physiotherapy modalities play an important role in restoring normal swallowing function, there is lack of comparative studies to determine the most effective modalities to be implemented in the rehabilitation program of acute stroke patients. This study aimed at comparing the effects of EMST and FES on the pulmonary and swallowing functions in these patients. After completion of this study, the results revealed the following:

In EMST group, EMST significantly improved patients' spirometric parameters (i.e., FVC, FEV1, FEV1/FVC and PEF). These parameters increased by 26.72 %, 34.27 % 6.7 % and 31.33 % respectively after receiving EMST for one month. Regarding swallowing function, the GUSS score in EMST group improved by 7.40 %. These percentages indicate that EMST strengthens expiratory muscles and leads to better breathing outcomes that can positively affect patients' swallowing and airway protection mechanisms. The results obtained come in agreement with those of Laciuga et al. [18] who included 24 selected articles in their narrative review regarding the effect of EMST on different measures including, but not limited to, the respiratory function, in form of: speech, voice, swallowing and coughing in patients affected by neurological diseases like Parkinson's disease,

Table 4. Comparison of the secondary outcomes in EMST and FES Groups

	Pre-treatment	Post-treatment			
	Mean ± SD	**Mean ± SD**	**MD**	**% of change**	***p* value**
PaO_2 (mmHg)					
EMST Group	88.36 ± 7.77	94.9 ± 8.71	−6.54	7.40	0.001
FES Group	87.13 ± 9.08	91.46 ± 7.4	−4.33	4.97	0.01
MD	1.23	3.44			
	***p* = 0.57**	***p* = 0.11**			
$PaCO_2$ (mmHg)					
EMST Group	48.7 ± 4.42	39.16 ± 2.15	9.54	19.59	0.001
FES Group	47.03 ± 6.41	41.17 ± 2.37	5.86	12.46	0.001
MD	1.67	−2.01			
	***p* = 0.24**	***p* = 0.001**			
SPO_2 (%)					
EMST Group	97.13 ± 1.43	98.53 ± 1.11	−1.4	1.44	0.001
FES Group	97.33 ± 1.39	98.16 ± 1.51	−0.83	0.85	0.002
MD	−0.2	0.37			
	***p* = 0.58**	***p* = 0.28**			
pH					
EMST Group	7.374 ± 0.029	7.402 ± 0.015	−0.028	0.38	0.001
FES Group	7.379 ± 0.033	7.398 ± 0.016	−0.019	0.26	0.002
MD	−0.005	0.004			
	***p* = 0.48**	***p* = 0.33**			
HCO_3 (mEq/L)					
EMST Group	27.46 ± 2.55	23.66 ± 1.34	3.8	13.84	0.001
FES Group	27.16 ± 3.07	24.46 ± 0.97	2.7	9.94	0.001
MD	0.3	−0.8			
	***p* = 0.68**	***p* = 0.01**			

Note: *SD — Standard deviation; MD — Mean difference; EMST — Expiratory Muscle Strength Training; FES — Functional Electrical Stimulation; PaO_2 — Partial Pressure of Oxygen in Arterial Blood; $PaCO_2$ — Partial Pressure of Carbon Dioxide in Arterial Blood; SpO_2 — Oxygen Saturation; pH — Potential of Hydrogen; HCO_3 — Bicarbonate.*

multiple sclerosis (MS), and Lance-Adams syndrome. The majority of the studies included in this systematic review revealed promising outcomes of EMST as a training for airway protection in patients with neuromuscular-induced dysphagia [18]. Another research by Lee et al. [19] revealed concomitant results after investigating the effects of EMST on pulmonary function (PF) and other functional parameters in chronic stroke survivors. They reported more significant improvements in PF in the study group participants than in controls and concluded that EMST significantly improves pulmonary function in stroke survivors [19]. A similar study by Park et al. [20] assessed the effects of EMST on the activity of suprahyoid muscles, risk of aspiration and dietary stages. They confirmed that EMST is an effective therapeutic method to facilitate the suprahyoid muscle and reported improvements in aspiration and penetration outcomes in patients with post-stroke dysphagia [20].

Conflicting results were reported in a systematic review by Templeman et al. [21] who included nine RTCs assessing the effect of EMST on Maximal expiratory pressure (MEP), PF and/or cough function in a variety of population including healthy adults, MS, COPD, acute stroke, and spinal cord injury. They reported an overall improvement in MEP following EMST but also reported no significant improvement in cough flow, FVC or FEV1 [21]. Another systematic review Mancopes et al. [22] included 11 relative articles assessing the effect of EMST on swallowing functions in different patient population. They reported no clinical significance in the swallowing function following the application of EMST. However, the included studies were limited by differences in the severity and aetiology of dysphagia in studied populations [22].

In the FES group, FES on the neck and abdomen led to statistically significant improvement in spirometric parameters (i.e., FVC, FEV1, FEV1/FVC and PEF) when pre and post treatment measurements were compared. These parameters increased by 16.67 %, 21.79 % 4.41 % and 13.60 % respectively. The percentages of improvement indicate that FES leads to better breathing outcomes and can positively affect patients' swallowing and airway protection mechanisms. The current results agree with those of McCaughey et. al. [17] who conducted a narrative review on FES in spinal cord injury patients. They concluded that FES of the abdominal muscles has a direct effect on the coughing of quadriplegic patients. After repeating FES for 6 weeks, improvement in unassisted respiratory function was observed, in addition to a decrease in ventilator duration, tracheostomy rate and cannulation time [17]. On the contrary, McLachlan et. al. [14] used functional electrical stimulation (FES) in patients with quadriplegic spinal cord injury who had low vital capacity and no observable abdominal movement. They revealed an immediate increase in FVC, FEV1 and PEF during training. However, they reported no significant change in the outcome measurements after 3 weeks of training [14].

Moreover, in 2019, McCaughey et al. [23] investigated the effect of abdominal FES on critically ill mechanically ventilated patients. They feasibility of FES in these patients and hypothesized that it can be an effective method to decrease mechanical ventilation and ICU stay. However, in their results, there were no differences in abdominal muscle or diaphragm thickness after FES McCaughey et al. [23] reported several limitations of their studies including the inability to directly measure the effect of FES on PF parameters due to the nature of the studied population, they also did not take into consideration the effects of ICU-acquired muscle weakness and the ventilator-associated muscle dysfunction in the studied parameters.

According to literature, ischemic stroke affects the respiratory system in many ways depending on the nature, site and extent of the lesion. The most common ABG presentation in acute stroke patients is respiratory acidosis. However, there are some reported cases who presented with respiratory alkalosis that are both often corrected by the metabolic component as a part of the body's physiological response. [5] This is concurrent with the findings of the present study that revealed respiratory acidosis in all of our included patients upon admission with different levels of physiological and iatrogenic compensation. The overall goal of the treatment was to observe the changes in ABG after treatment, if any. At the end of the study, there was a significant increase in pH, PaO_2, and Oxygen saturation post-treatment compared to pre-treatment values, with no significant differences between the two groups. Moreover, there was a significant decrease in $PaCO_2$ and HCO_3 to normal levels post-treatment compared to pre-treatment in both groups with EMST group values showing more significant decrease compared to those of FES group. These results indicate that both EMST and FES can positively affect the ABG values in post-stroke patients. However, this study did not consider the speed of ABG normalization in each group, which could have been another indicative factor of effectiveness. It is recommended to conduct further studies in this area while closely monitoring ABG changes in a shorter time window.

In the present study, although FES led to significant increase in all measured spirometry parameters and GUSS scores, when the effects of EMST and FES were compared together, it was evident that EMST led to more significant increase in FVC, FEV1, PEF and GUSS scores compared to FES. Which provides more evidence that active involvement of muscles in rehabilitation yields better improvement in muscle outcomes. This indicates that for future treatment plans, both EMST and FES can be used in combination or independent from one another. However, the present study does not favour one modality over another; EMST may be favourable for conscious, cooperative patients who have no health and physical problems preventing them from using an EMST device. Yet, FES can be the ideal for use in unconscious, uncooperative patients who will not be able to actively participate in the treatment session or for those who cannot effectively use EMST devices (e.g., facial nerve palsy) and can also be started earlier in the rehabilitation plan than EMST.

Limitations

Due to ethical considerations, there was no control group to compare the treatment-induced changes to a no-intervention group. As there is plenty of research proving the effectiveness of both modalities, using one of the modalities was necessary for all patients to improve the recovery outcomes. In addition to that, time factor was also considered a limitation in this study when it comes to the secondary measured outcomes; according to mixed MANOVA statistical analysis, the time factor interfered with the treatment plan due to the expected physiological buffering of blood pH values. In other words, the study lasted for one month and pre- and post-treatment

evaluations were carried out with a one-month-gap. During this time, physiological compensation was normally expected to occur provided that patients with renal problems were already excluded from the study. Moreover, there are other external factors that were not taken into consideration in this study; for instance, the type of respiratory failure and the external correction measures that might have been taken prior to study inclusion in emergency settings or during ICU stay, such as mechanical ventilation and intravenous corrections which requires further research in the future.

CONCLUSION

EMST was more effective than FES in improving patients' expiratory functions and patients' swallowing functions in a post-stroke dysphagia. However, both techniques can be effectively and safely implemented in the treatment of dysphagia.

ADDITIONAL INFORMATION

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